CAPABILITIES IN NUCLEAR WEAPONS EFFECTS RESEARCH

1965

U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION

CORPS OF ENGINEERS

Vicksburg, Mississippi

WATERWAYS EXPERIMENT STATION CAPABILITIES

The booklets listed below describe, for record purposes and the information of potential users, major special capabilities of the U. S. Army Engineer Waterways Experiment Station.

Summary of Capabilities

Capabilities for Resolution of Hydraulic Problems Through Model Studies

Capabilities in Hydraulic Prototype Analysis

Capabilities in Earthwork Engineering

Capabilities in Soil Stabilization for Military Purposes

Capabilities in Soil Dynamics Research

Capabilities for Evaluating Environmental Effects on Military Operations

Capabilities in Mobility and Trafficability Research

Capabilities in Flexible and Prefabricated Pavement Design

Capabilities in Surface Blast Effects Research

Capabilities in Concrete Research

Capabilities in Nuclear Weapons Effects Research

Capabilities in Instrumentation

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WATERWAYS EXPERIMENT STATION

Organization and functions

The Waterways Experiment Station is the principal laboratory facility of the Corps of Engineers, U. S. Army. It is engaged in research and engineering investigations in the scientific fields of hydraulics, concrete, soil mechanics, mobility of military vehicles, nuclear weapons effects, and flexible pavement design. Through basic and applied research in these and related fields, the development of methods and techniques, and the testing of materials and equipment, it assists in the accomplishment of both civil works and military missions of the Corps of Engineers. Because of its nationwide scope of activity, the Waterways Experiment Station operates under direct control of the Chief of Engineers. It serves all offices of the Corps on a reimbursement basis, and its capabilities are available on the same basis to other Federal and Defense agencies.

Five engineering research divisions, the Hydraulics, Soils, Concrete, Nuclear Weapons Effects, and Mobility and Environmental Divisions, are directly responsible for accomplishment of the overall mission in their respective fields of endeavor. A Technical Services Division provides essential technical support in instrumentation, data reduction and computation, special library services, etc., and performs additional work for the Corps within its capabilities. A Construction Services Division supports the basic work programs with its full range of shops, maintenance, and light and heavy construction facilities. Since the end result of every investigation is a technical report, unusually effective central facilities are maintained for the production of technical reports. The functional organization is completed by the presence of all normal administrative services.

Physical facilities

The Waterways Experiment Station occupies two government-owned reservations containing buildings, test sites, specialized equipment, and other plant facilities necessary to the accomplishment of its mission. The Vicksburg reservation has an area of about 400 acres and contains the main administrative headquarters and all organizational elements except the Concrete Division. The Jackson reservation has an area of about 820 acres and is the site of the Concrete Division and a 220-acre hydraulic model of the Mississippi River watershed. The prevailing mild climate permits almost uninterrupted outdoor testing throughout the year.

Personnel resources

The Director of the Waterways Experiment Station is a career officer of the Corps of Engineers. The civilian staff normally consists of about 1200 employees, many of whom are professional engineers and scientists of recognized standing in their respective fields, which include all major disciplines of engineering and the physical sciences. The

professional staff numbers over 300 and includes civil engineers who are specialists in hydraulics, soil mechanics, and concrete experimentation and research, as well as electrical, electronic, mechanical and materials engineers. Other scientific personnel include physicists, chemists, mathematicians, geologists, geophysicists, etc. Technicians and assistants, representing a broad range of specialized skills and knowledge, comprise another substantial portion of the staff. The technical capability is further enhanced by the services of leading consultants, on a contract basis, who are drawn from among recognized authorities at universities and in industrial or professional life. This combination of available talent produces a technical capability of such breadth and versatility that the Waterways Experiment Station can successfully undertake expanded programs in either present or additional investigative fields.

NUCLEAR WEAPONS EFFECTS DIVISION

Research concerned with nuclear weapons effects is conducted by the Nuclear Weapons Effects Division for the Army in cooperation with other Department of Defense agencies utilizing theoretical, analytical, and experimental methods. The experimental work is carried out by means of small-scale high-explosive tests, special laboratory tests, and full-scale nuclear tests. Investigations are concerned chiefly with the design of protective structures to resist blast and with underwater shock effects. The Division also participates in the Plowshare program of the Atomic Energy Commission and provides consultant-type services to Office, Chief of Engineers, Office, Civil Defense, Defense Atomic Support Agency, and other government agencies active in this field.

NUCLEAR WEAPONS EFFECTS RESEARCH FACILITIES

Development

Early in 1951 the Waterways Experiment Station was selected to conduct an extensive research program in which high explosives were used to study the effects of explosions in shallow water. This represented the Experiment Station's first effort in the explosion-effects field. During this initial program, measurements of air blast, water shock, cratering, and water-surface waves were obtained. The experience gained by personnel and the instrumentation facilities acquired were subsequently used to accomplish explosion-effects research for several Department of Defense organizations. In June 1955, the Waterways Experiment Station was assigned an Army R&D Project with the main objectives of: (a) determining the effects of nuclear weapons on structures, terrain, and waterways so that planning data might be provided as needed for both offensive or defensive operations, and (b) developing criteria for use in designing underground structures for protection of personnel and equipment. Since 1955, the work has expanded greatly to include weapons effects research studies for the Defense Atomic Support Agency, the Departments of the Navy and Air Force, and the Office of Civil Defense.

Theoretical and analytical studies, small-scale high explosives tests, and special laboratory tests are utilized to determine the basic effects of nuclear detonations, and to describe the damage that these effects will have on targets such as dams, airfields, harbors, terrain features, and underground structures. Supporting data and additional information are obtained by participating in full-scale weapons tests and in large HE test programs. Through the various research programs certain testing facilities have been acquired or developed which add to the Experiment Station's capabilities in the nuclear weapons effects field. Descriptions of some of these facilities follow.

Test site

The Big Black Test Site is a 13.8-acre area located approximately 10 miles southeast of the Experiment Station on the west bank of the Big Black River (fig. 1). In addition to areas allotted for conducting cratering and topography studies, two test basins are available. The first is a shallow-water basin 160 ft wide and 260 ft long which can accommodate water depths up to 12 ft and HE charges up to 1000 lb. The other is a trapezoidally shaped deep-water basin, 150 ft wide and 250 ft long, which can accommodate water depths up to 22 ft and HE charges up to 100 lb (above or below the water surface). The deep-water basin is equipped with the necessary rigging, pulleys, and winches to facilitate the positioning of gages, charges, etc., at any location between the bottom of the basin and 60 ft above the

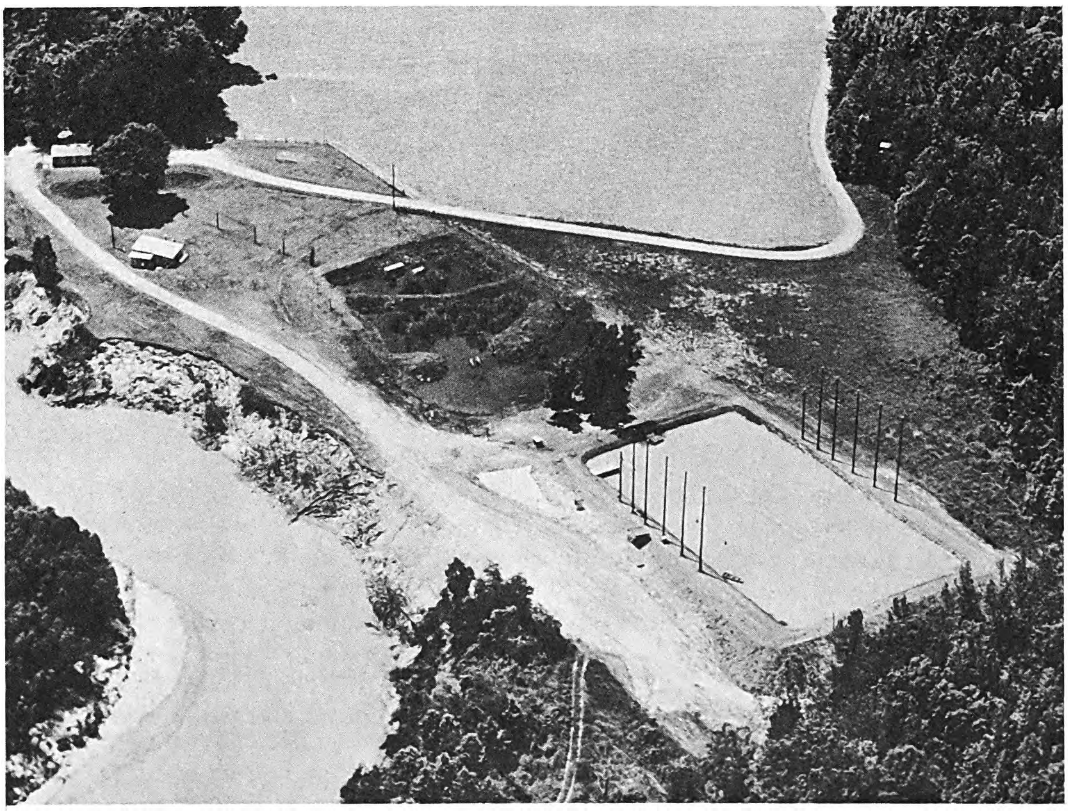

Fig. 1. Test site on west bank of Big Black River

basin rim. Two trailers and a 20- by 50-ft temporary building are available for instrumentation housing. Thirty-six channels of high-speed electronic recording equipment are permanently installed at the test site with an additional 70 channels of medium-speed recording equipment available. The nearest habitation in the vicinity of the test site is about 2 miles away.

Explosive casting facility

In order to conduct explosion-effects studies more efficiently and economically, the Experiment Station has constructed a TNT melting and casting facility (fig. 2). It is possible to melt and cast charges into various shapes and sizes up to 300 lb in weight in a single pouring. Present daily capacity is limited only by the number of molds.

Fig. 2. TNT melting and casting facility for conducting explosion-effects studies

Shock tube

The shock tube is used primarily in gage-development work and as a gage-calibrating device. The tube (fig. 3) has a uniform cross section of 4 in. by 8 in. (inside) with a 5-ft compression chamber and a 14-ft expansion chamber. Unreflected peak pressures up to 35 psig are obtainable. The maximum duration of the flat-top portion of the pressure wave is approximately 7 milliseconds. Instrumentation is provided to measure pressure as a function of time at locations along the expansion chamber.

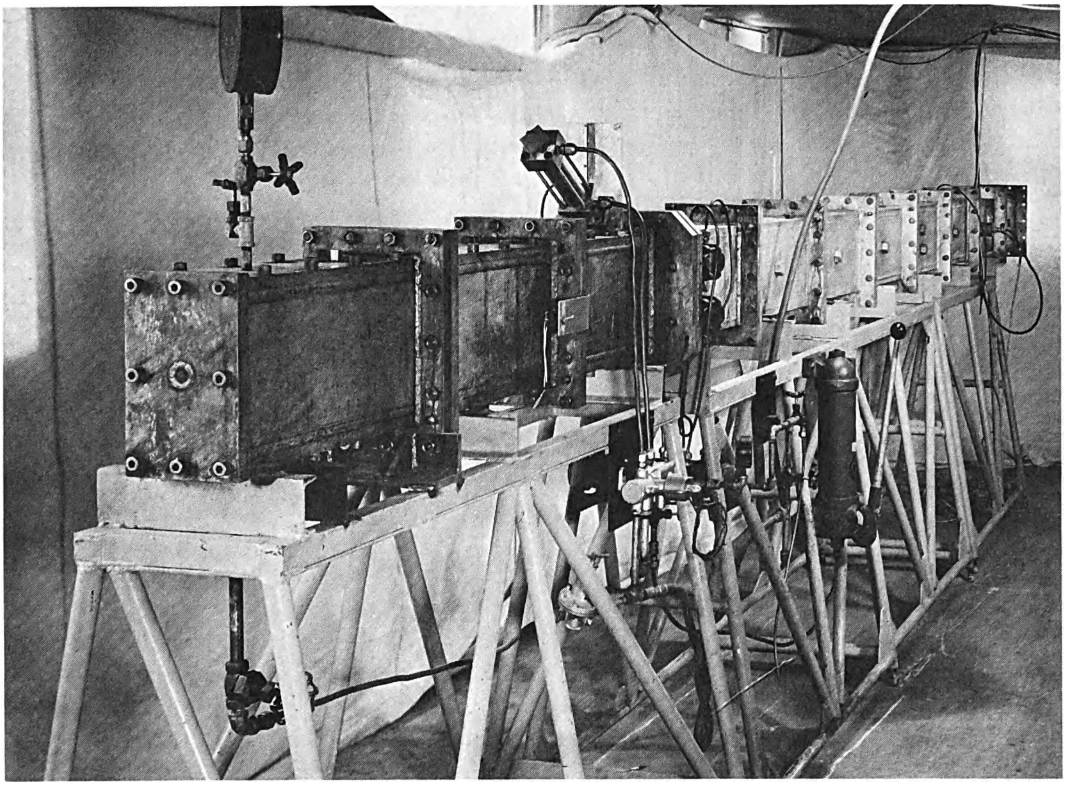

Fig. 3. Shock tube

Large blast load generator

The large blast load generator is a three-dimensional device designed primarily to test underground protective structures subjected to pressures simulating those generated by both kiloton and megaton nuclear devices. Pressures from 30 to 450 psi having rise times of approximately 2 to 4 milliseconds and durations approaching 2 seconds can be produced in the generator. Static pressures up to 1000 psi can be sustained when modifications on the test chamber are complete.

The large blast load generator consists of two basic components: the central firing station and the test chambers. The central firing station (fig. 4) is a massive, posttensioned, prestressed concrete, reaction structure designed to resist the large dynamic or static loads generated in the test chamber. The two test chambers are cylindrical steel bins 23 ft OD, 22 ft 10 in. ID, that contain the test media and test structures. A test chamber consists of three C rings that stack to a height of 10 ft, one B ring that contains 15 firing tubes, and one A ring that is a telescoping-type lid. The A and B rings are interchangeable with the other set of C rings. The central firing station and test chamber are housed in a large laboratory building equipped with overhead cranes, special handling equipment, instrumentation, and offices (fig. 5).

The explosives in the firing tubes (PETN in the form of primacord) are fired electrically by a standard engineer cap connected to a leader strand of primacord. The leader strand is connected to individual strands of primacord that lead to each tube.

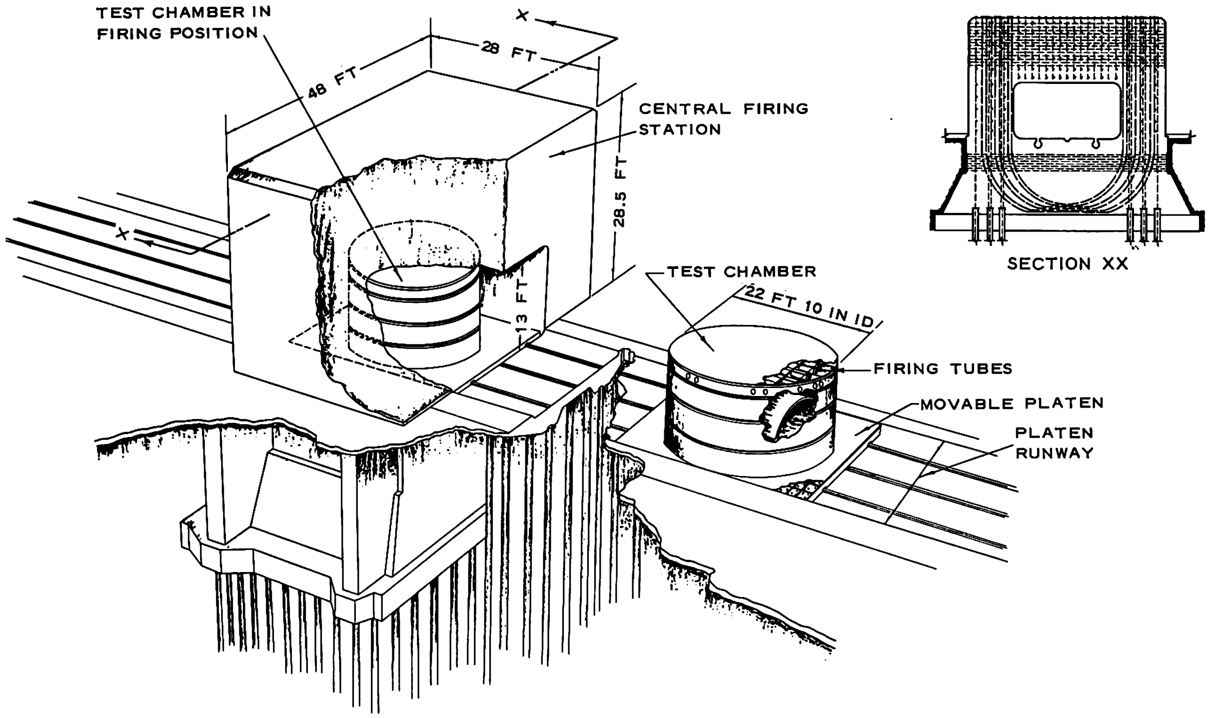

Fig. 4. Schematic drawing of large blast load generator central firing station and test chamber

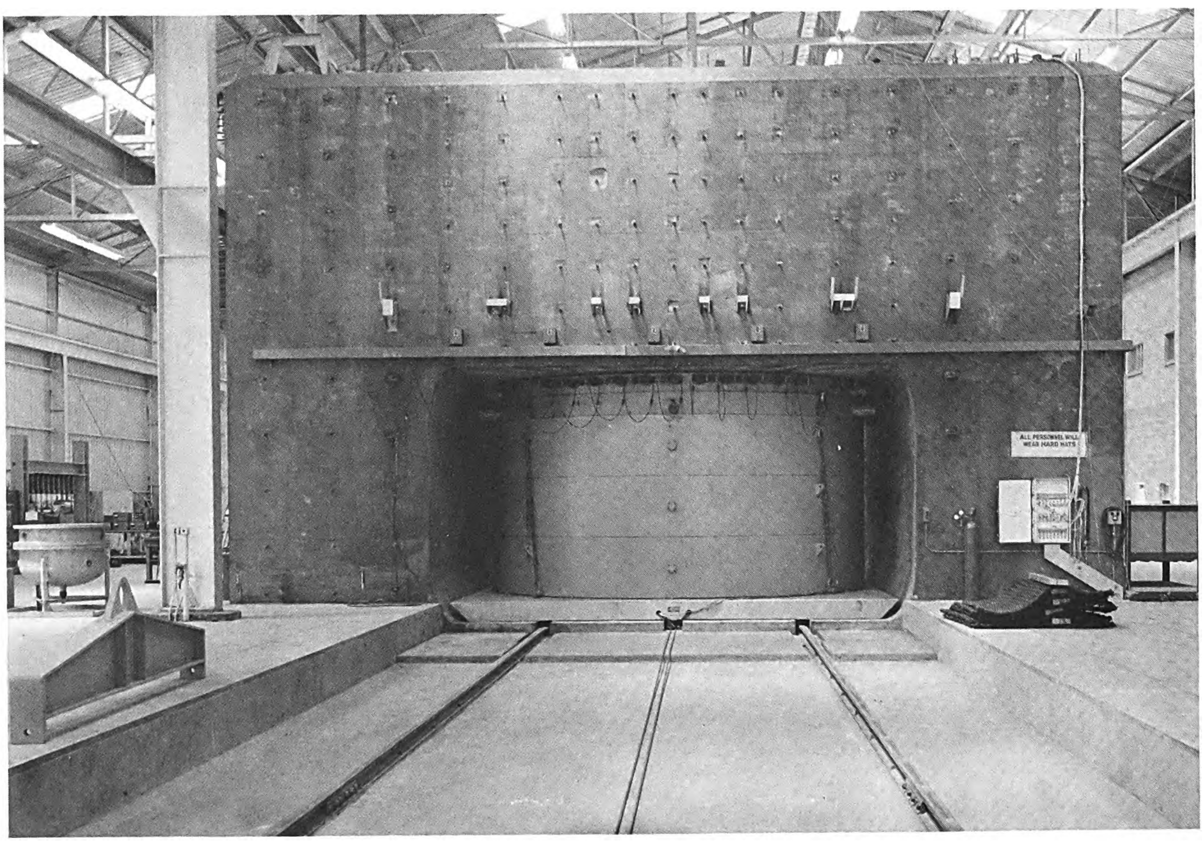

Fig. 5. Large blast load generator with test chamber in firing position

The device is used in various types of investigations. Studies are made in the design and analysis of the response of underground structures to dynamic loads to determine effects of the shape of the structure, of the ratio of span length to depth of burial, of the ratio of span length to the overall length of the structure, of structural flexibility, and of the ratio of the duration of the loading to the natural period of the structure.

Other studies are concerned with the response of various types of soils to dynamic loads, shock isolation methods, stress wave propagation in soils, blast-closure devices, and the design of entranceways and entrance closure methods.

Small blast load generator

To design the large blast load generator, certain information was required which could be obtained only by direct experimentation. Consequently, a 4-ft-diameter generator was constructed and used to obtain these data. The small blast load generator is now a companion to the large blast load generator and is located in the same building. It is used to evaluate designs and to verify design procedures for underground protective structures.

The small blast load generator (fig. 6) can produce static pressures up to 500 psi and dynamic pressures up to 250 psi having a minimum rise time of 4 to 5 milliseconds and durations in excess of 2 seconds. The generator has a 9/16-in.-thick, steel, cylindrical shell and an elliptical dome top called the bonnet. It is shown in position on top of the rigid bottom in the left side of fig. 6. The shell is composed of a series of stacked rings (46-3/4 in. ID) of various depths that are bolted together to allow the depth of a soil sample to be varied. Sealing is provided by O rings in the separating flanges.

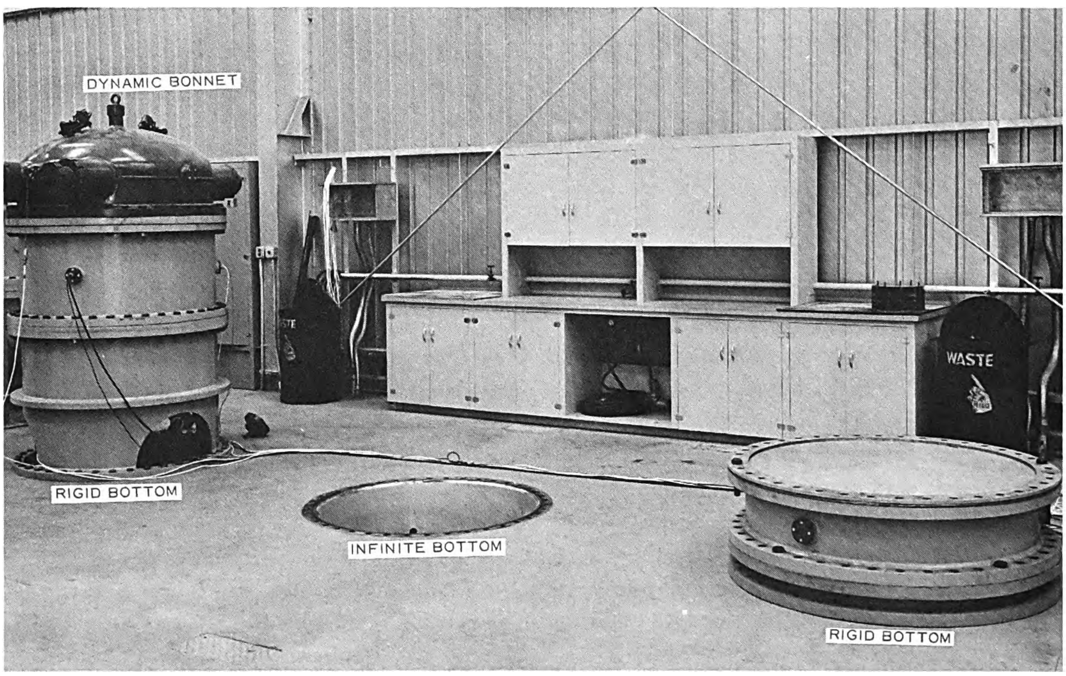

Fig. 6. Small blast load generator

The concrete foundation to support the generator is 9-1/2 ft thick and has three anchorage locations, i.e. two rigid bottoms and one infinite bottom (fig. 6). One of the rigid bases has a flat concrete interface at the base and the other provides an anchorage for a cylindrical ring having a flat steel bottom plate 1 in. thick and heavily stiffened. In the center of the steel bottom a trapdoor can be mounted (maximum diameter 6 in.), and at various locations on the plate pressure transducers can be mounted. The infinite bottom is a 9.5-ft-deep, steel-lined hole in the base slab. The interface between soil specimen and base is the subsoil which is clay. With this base, a specimen up to 20 ft long, 46-3/4 in. in diameter, and with essentially no horizontal reflecting interface, can be tested.

The dynamic bonnet houses two firing tubes surrounded by a baffle grid. The detonation of explosives (PETN in the form of primacord) in the two firing tubes generates pressure which loads the soil surface. The baffling grid breaks up the shock fronts and helps to form an essentially plane wave (within 8-10 percent) over the sample surface.

The small blast load generator is equipped with two quick-opening valves which can be timed to open automatically at 0.3, 0.6, 0.9, 1.2, 1.5, or 1.8 seconds after firing, or they can be operated manually. The body of the generator contains about (depending on the type base used) 10 ports for the insertion or mounting of pressure transducers, accelerometers, and other instrumentation.

200-kip loader

The 200-kip loader is a new testing device capable of applying a concentrated load in short times over a maximum stroke of 4 in. (fig. 7). The loader is generally scheduled for full-time use on Defense Atomic Support Agency programs; however, tests may be conducted for other agencies on a priority basis.

This loader is a companion to the 500-kip loader (fig. 8). Together they provide a capability for testing structural shapes with loading rates varying from slow static loads to those at which the maximum load is reached in a very few milliseconds.

The 200-kip loader is designed to apply forces varying from 10,000 to 200,000 lb in either tension or compression. The design of the device is such that loads as high as 400,000 lb may be possible; however, definition of the maximum load capability of the device is subject to further evaluation.

The minimum time required to develop a specific load is affected by many variables, including piston location, magnitude of load, response of resisting member, and characteristics of the control valves, etc.; therefore, the rise-time characteristics of the loader are a function of the test conditions. A minimum rise time of 1.3 milliseconds for a load in excess of 200,000 lb with approximately 1/4 in. movement of the piston has been obtained with the device.

Accuracy and ability to obtain hold times in the millisecond range cannot be defined at this time, and considerable experience is needed in operating the loader before load-time histories can be defined adequately.

The types and sizes of specimens that can be tested include: beams up to 24 in. deep, 18 in. wide, and 144 in. long; columns with a maximum height of 6 ft and cross-sectional diameter of 18 in.; circular specimens having a maximum diameter at the grips of 2-1/2 in. and length of approximately 36 in. under tensile loading; and members requiring 2-point loading with up to a maximum of 4 ft between points of load application.

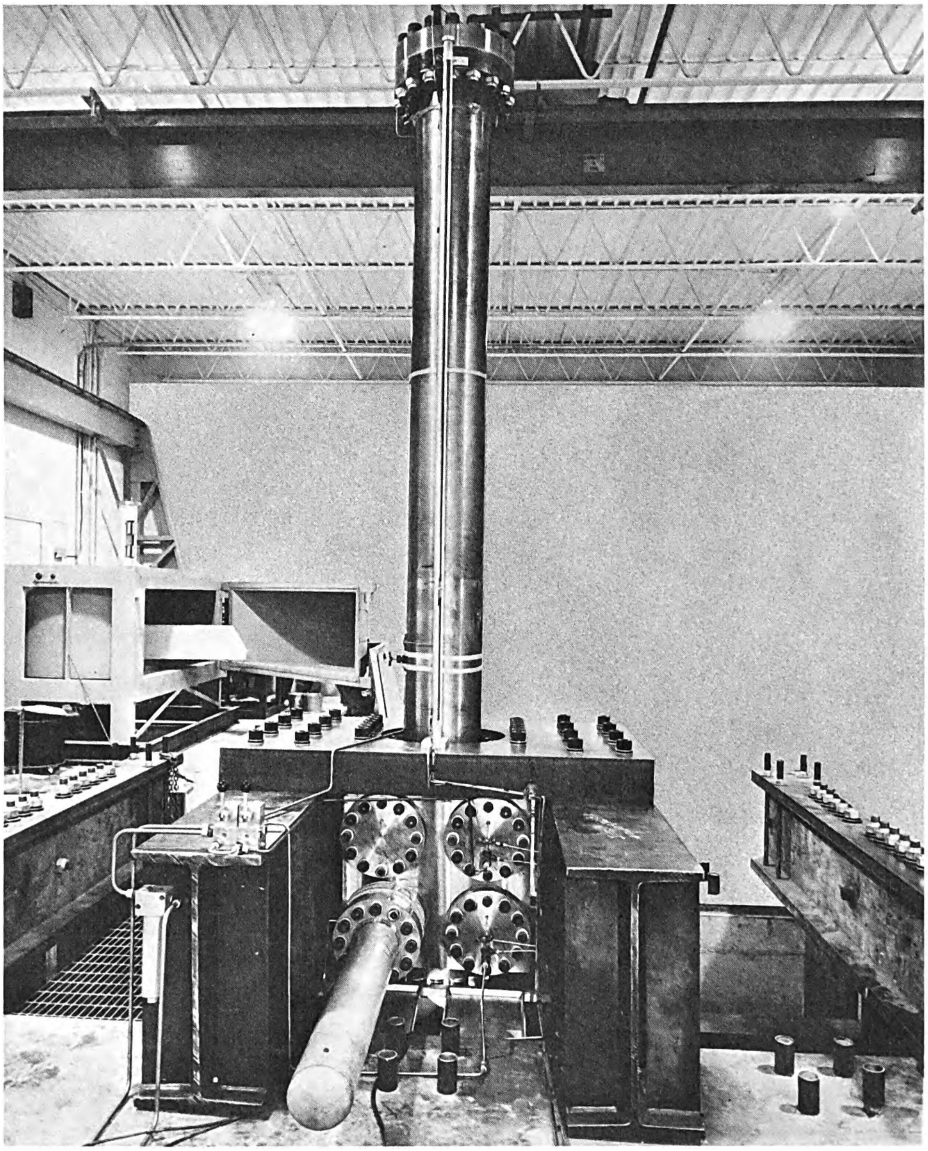

Fig. 7. 200-kip loading machine

500-kip loader

The 500-kip loader (fig. 8) is a servo-controlled, hydraulic device capable of producing loads to 700,000 lb. The loader is normally used full time on Defense Atomic Support Agency studies; however, other test programs may be conducted on a priority basis.

This loader provides the capability of reaching maximum load in times varying from a few milliseconds down to essentially a static load (fig. 9). The device may be located over the same 8-ft-deep, 5-ft-wide, and 25-ft-long pit used for the 200-kip loader, or it may be placed on a 12-ft-high test stand that is independent of the pit area.

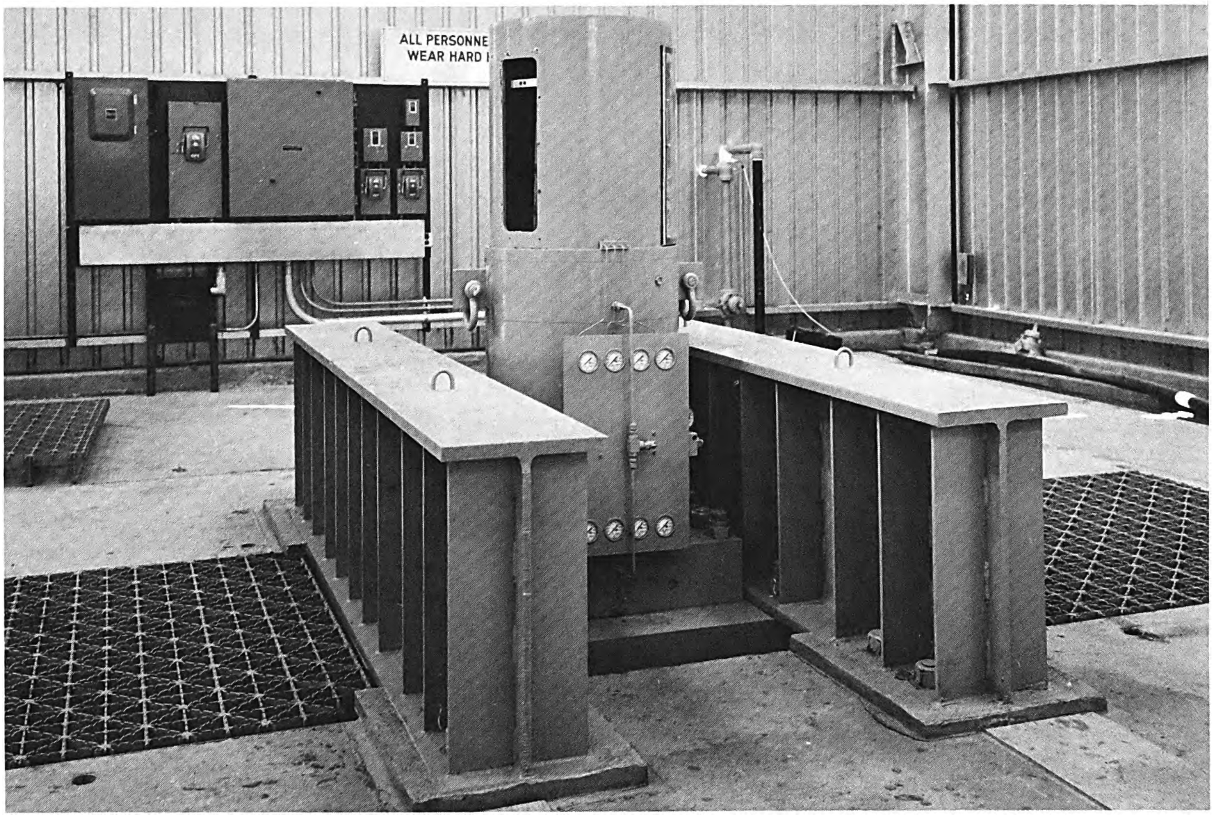

Fig. 8. 500-kip loader

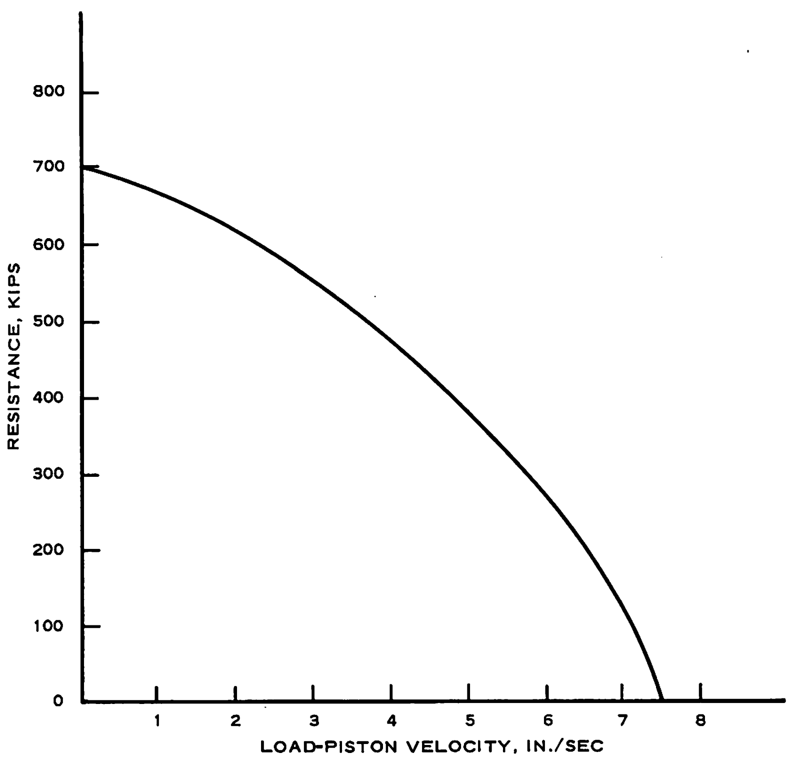

Fig. 9. Load-velocity capability, 500-kip loader

Primarily, the loader is used to determine the effect of strain rate on the strength characteristics of various structural and engineering materials in both tension and compression under either transient or static loads.

50-kip loading device

This machine (fig. 10) is a gas-operated, hydraulically and electrically controlled, piston-type loading machine capable of producing static and dynamic loads up to 50,000 lb. The rise time of the load is a function of the rate of deformation of the material being tested and the peak load applied. For dynamic loads in the range of 3,000 to 5,000 lb, commonly used for small-scale footing tests on soils, the minimum rise time is about 8 milliseconds. The load rise time can be controlled from the minimum time to about 150 milliseconds. The load dwell time can be controlled from 0 to 1 second, and the load

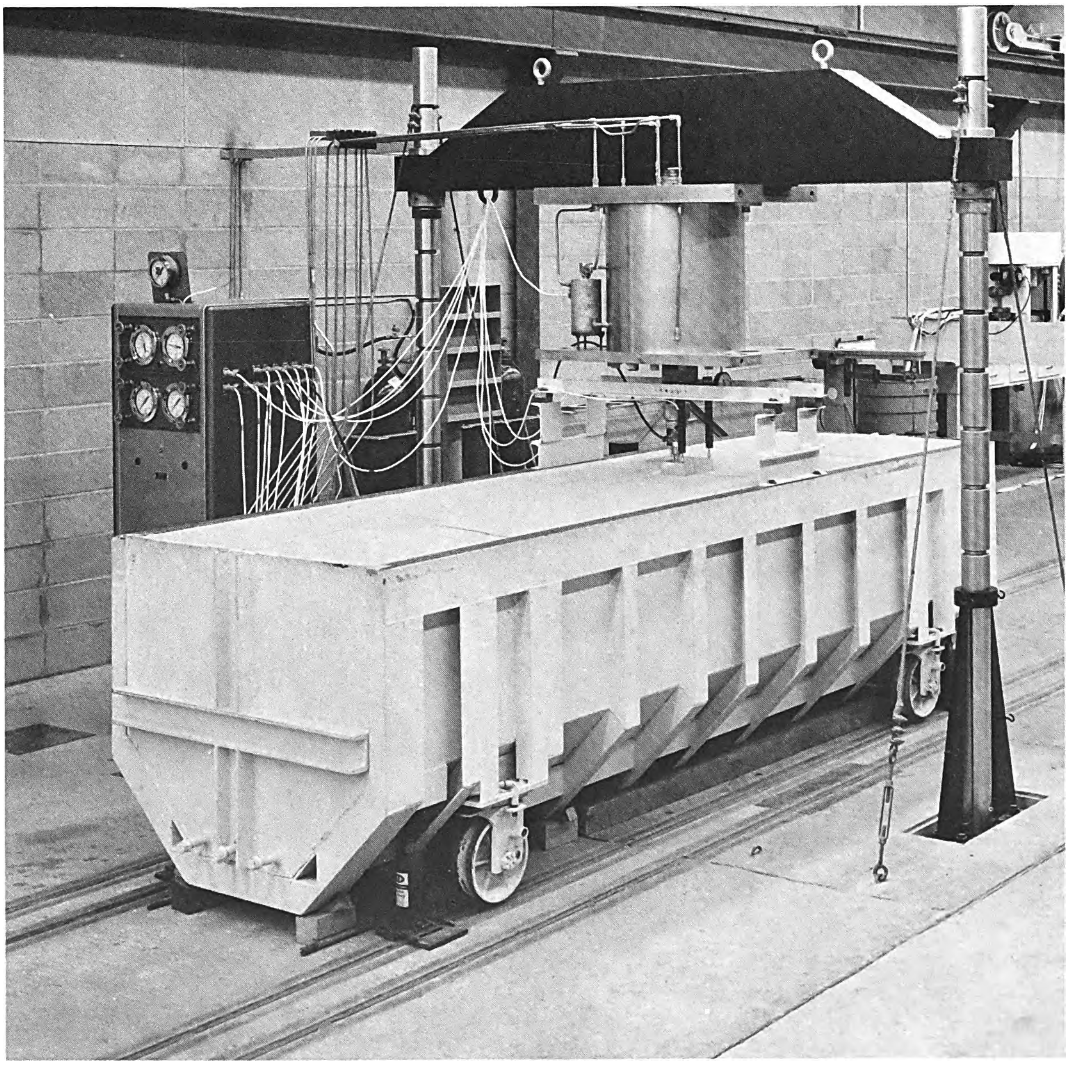

Fig. 10. 50-kip loading machine

decay time from 0.02 to 10 seconds. The device was installed in November 1959, and small-scale footing tests are currently being conducted.

Three-unit uniform loading device

This equipment consists of three geometrically similar units of varying capacities (fig. 11). Each unit has nine hydraulic cylinders for applying a uniform load or point loads to a structural test specimen, i.e. beams, arches, etc. A uniform load or point loads are applied by closing any combination of hydraulic cylinders in the system.

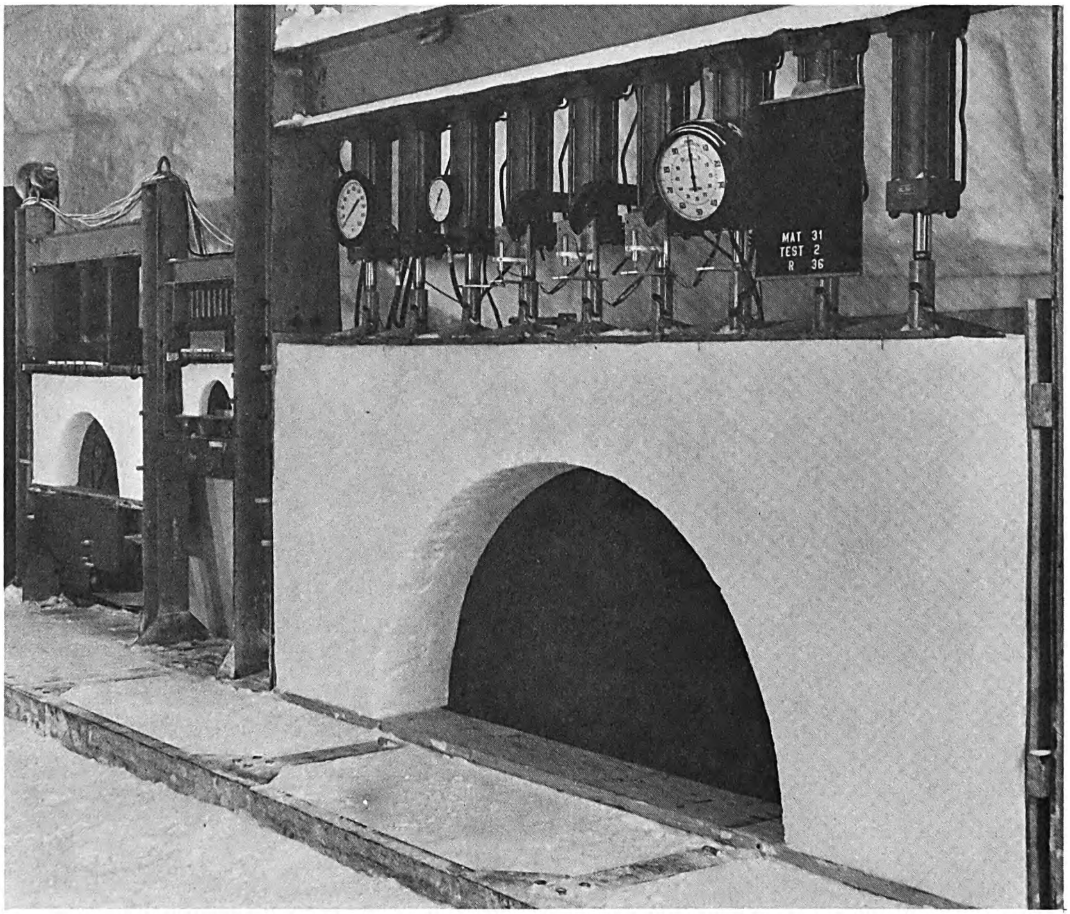

Fig. 11. Three-unit uniform loading device

Surface and underground explosion test box

The explosion test box provides a convenient means for observing small-scale explosions in selected media (charge size on the order of several grams). High-speed

photography is used to record actual crater formation, throwout, and related phenomena. The box, shown in fig. 12, permanently inclosed on all sides except top and front, is 4 ft square and 3 ft deep. A removable plexiglass plate, 1 in. thick, is used to seal the front of the box and to permit observation of the crater-formation process. It is particularly useful in studying half-craters formed by hemispherical charges detonated against the plexiglass front.

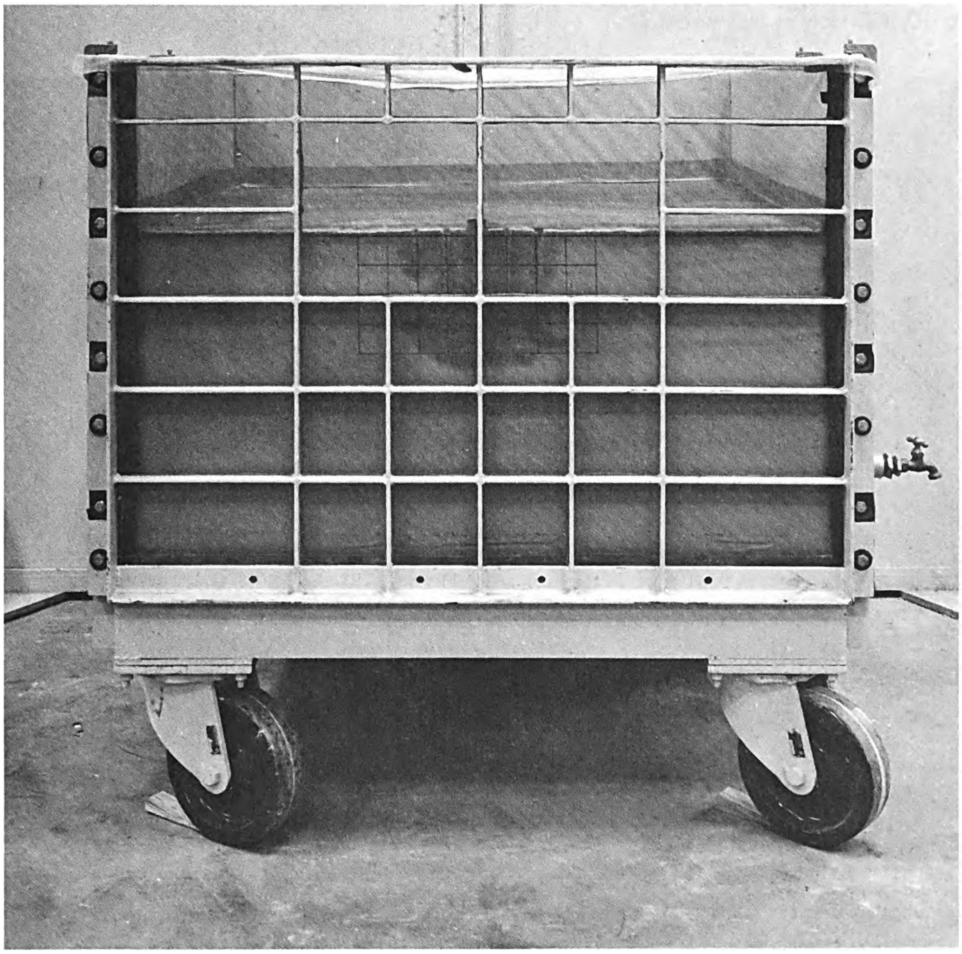

Fig. 12. Explosion test box

Ripple tank

The ripple tank provides a test basin that is 3 ft by 4 ft in plan; water depths up to 6 in. can be accommodated. The facility has point source ripple generators or linear generators for simulating explosion-produced wave systems or wind-wave systems, respectively. Viewing is accomplished by reflecting through two 45-degree mirrors.

Underwater explosion test tank

The underwater explosion test tank is 7 ft in diameter and 7 ft deep (fig. 13). The tank is equipped with two photographic ports that are diametrically opposed so that back-lighting is feasible. The tank can accommodate the firing of charge weights up to 100 grams, provided the charges are detonated at the center of the tank. The facility is particularly suited to photographing underwater explosion bubbles by means of high-speed photography (up to 10,000 frames per second).

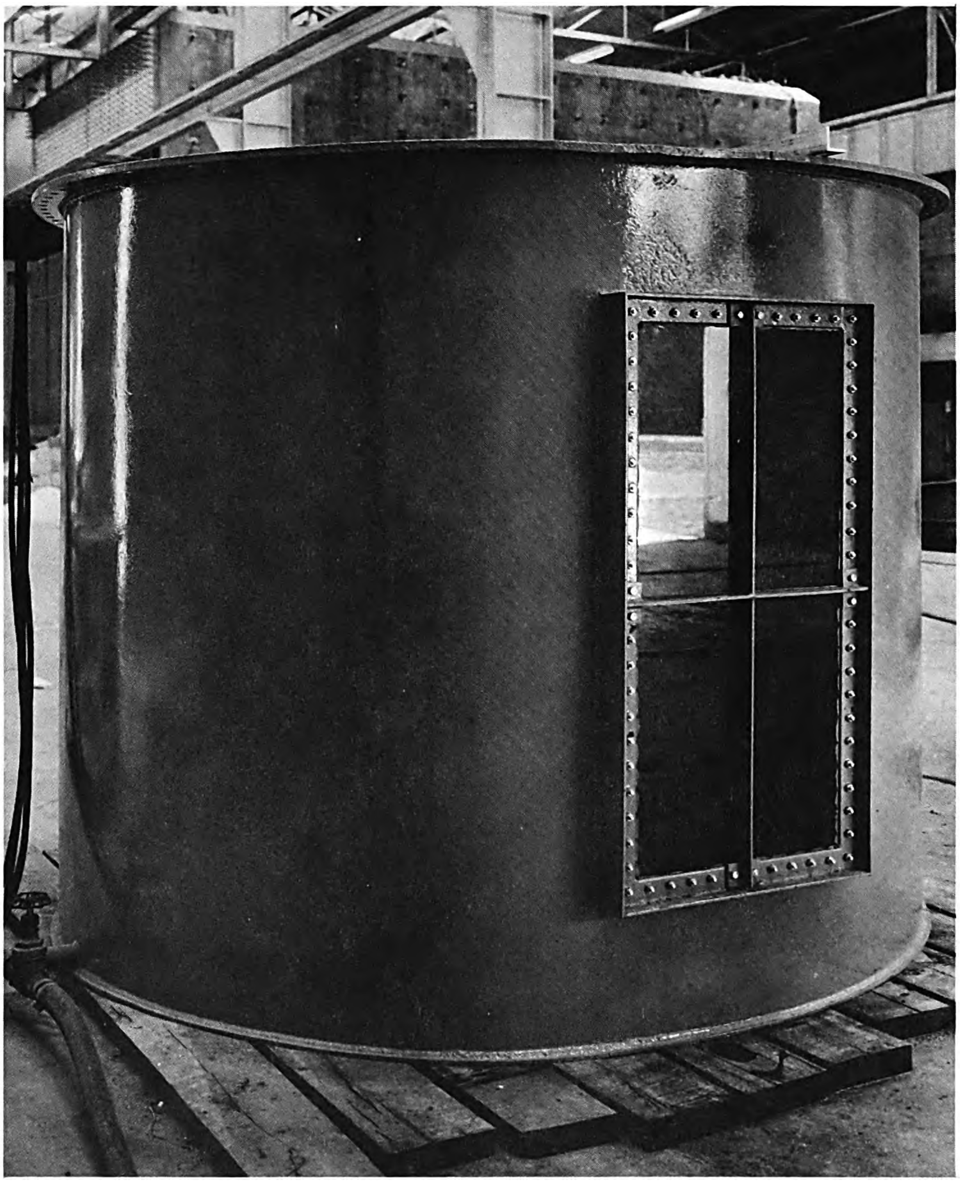

Fig. 13. Underwater explosion tank

Weapons effects instrumentation and test apparatus

Approximately 250 channels of instrumentation are available for recording weapons effects data (fig. 14). Frequencies ranging from zero to 8 megacycles per second are covered with this apparatus. Included are galvanometer, magnetic-tape and cathode-ray oscilloscopic recorders; and carrier frequency, direct-current and frequency modulation (FM) electronic amplifier systems. A wide variety of transducers is available for sensing physical variables. Details of the instrumentation are found in the booklet entitled *Capabilities in Instrumentation*.

Auxiliary apparatus includes a rotary centrifuge for calibration of accelerometers to 1,000 g, a drop table for studying dynamic response of various transducers and components, analog-digital conversion equipment for reduction of data, and an analog computer for simulation of physical and mathematical systems.

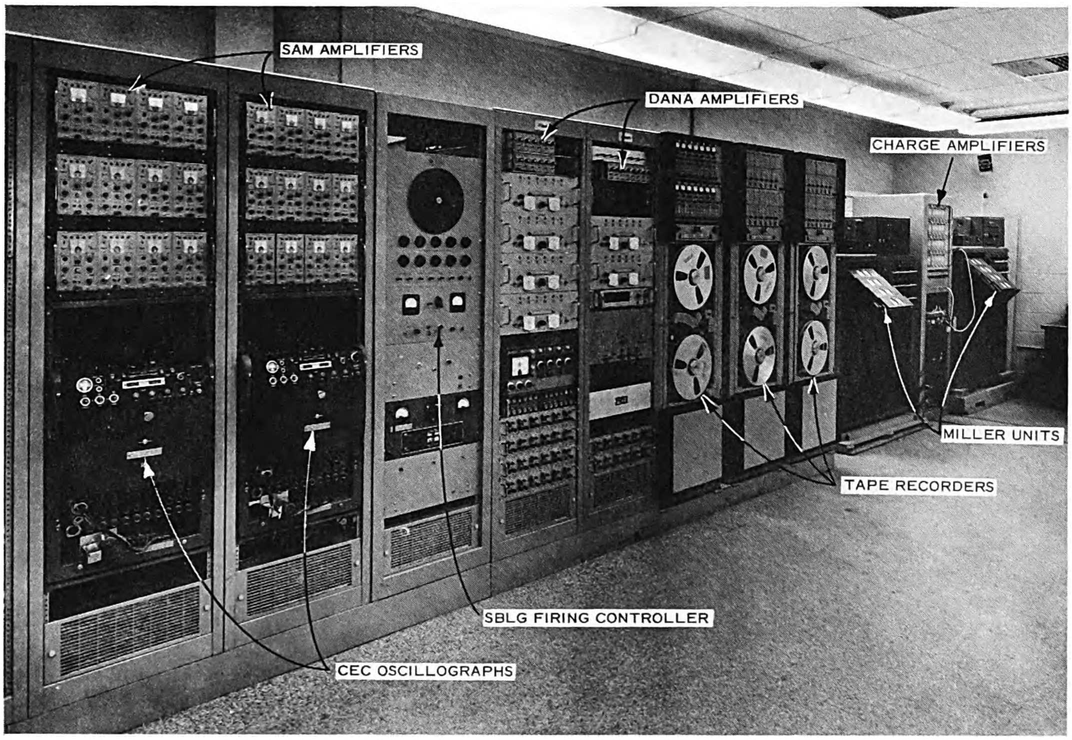

Fig. 14. Test instrumentation

Standard testing devices

Many other standard testing devices are also available. Among these are water tunnels, vacuum apparatus, flumes and pressure tanks of various sizes, as well as many types of mechanical and electronic instrumentation.

Full-scale nuclear test support

With its laboratory facilities, mobile equipment, and trained personnel, the Waterways Experiment Station is experienced in providing certain unique services in support of full-scale nuclear weapons testing. These services include:

Geologic studies and analysis of earthwork problems.

Soils explorations and testing including subsurface explorations by rotary drilling methods.

Soil analyses and backfill control.

Complete grouting services including equipment for drilling grout holes, and batching, mixing, and injection of grout in the field.

Blast and shock phenomena measurement in the air, underground, and underwater.

Measurement and analysis of the response of structures or structural components to blast or shock phenomena.

Measuring crater size and shape, debris distribution, and delineation of plastic-elastic response boundary.

INQUIRIES

Inquiries concerning the possible use of these or other special capabilities of the Waterways Experiment Station are welcomed and should be addressed to:

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